October 2024

Institute for Energy Economics
and Financial Analysis

Industrial heat pumps key to addressing excess gas demand

Harnessing industrial heat can cut gas use by 17%

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Key Findings

Heat pumps could electrify industrial processes below 250°C and replace up to 17% of Australia's gas use.

Applying commercially available heat pumps in the food and beverage sector could replace 29PJ of gas and reduce Victoria's industrial gas use by 36% in 10 years.

Shifting from gas to heat pumps in alumina refining could reduce WA's gas use by 10% and help alleviate upcoming excess gas demand, but it needs pilot trial support.

In the food and beverage and alumina sectors, heat pumps could cut energy use by 80% or more and eliminate emissions if powered with renewables.

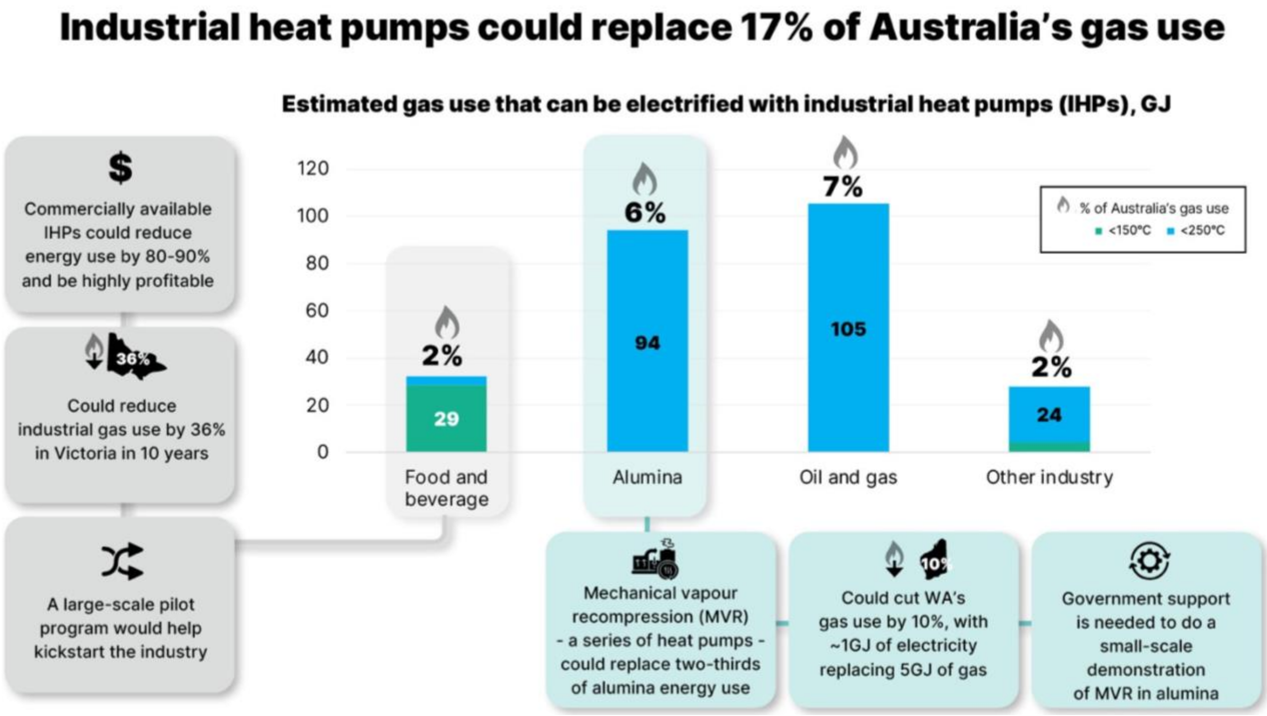
Executive Summary

The technology landscape of industrial heat pumps (IHPs) is developing rapidly. Models capable of providing process heat up to 150°C have already been implemented in multiple commercial settings. New solutions, involving either emerging technologies or “cascaded” systems, can reach 280°C.

In total, IHPs could replace more than half of the gas used for Australia’s industrial process heat, or about 17% of domestic gas use. The two most prospective applications are in the food and beverage (F&B) sector and alumina refining. Commercially available IHPs could replace 29 petajoules (PJ) of gas use in F&B. The application of mechanical vapour recompression (MVR), which works as a series of open-cycle heat pumps, in alumina could cut gas use by 94PJ but needs demonstration.

The opportunities are concentrated in Victoria and Western Australia (WA) respectively, two states facing large excess gas demand in the coming decade. IEEFA calculates that commercially available IHPs in the F&B sector could reduce gas demand by about 14PJ in the next 10 years in Victoria, cutting the state’s industrial gas use by 36%. In WA, MVR could deliver gas demand reductions in the next decade equivalent to 10% of the state’s total gas consumption today.

Figure 1: The potential of IHPs to reduce Australia’s gas use



Source: IEEFA

Despite this, IHPs seem absent from government plans, and the Australian market lags its global peers. IEEFA recommends the government support a large-scale pilot program focused on implementing heat pumps in the F&B sector. Such a program could help build better data, expertise and supply chains for IHPs in Australia. In parallel, government should also support the small-scale demonstration of MVR in the alumina sector. Although an MVR pilot project at Alcoa's Wagerup facility in WA was recently closed due to higher-than-expected costs, the company believes there is still a potential role for MVR in decarbonising the alumina industry and has emphasised the need for successful small-scale demonstration of MVR to derisk investment for larger-scale deployment.

Heat pumps are increasingly recognised as a critical technology to support electrification, with mature applications in buildings and emerging applications for industry. One of the main benefits of IHPs is their high efficiency – they can typically provide heat with an efficiency of 250-400%, and even above 500% for lower temperatures. This means that for every unit of electricity consumed, an IHP can produce 2.5-5 units of heat. In contrast, fossil fuel-based thermal systems typically have efficiencies of 50-80%, and as low as 30% in some cases. This means IHPs can likely deliver energy savings of at least 68-90% compared with traditional thermal systems. IHPs are most compelling when they can replace an inefficient centralised thermal system (e.g. with high distribution losses and oversized to cater for the highest heat requirements) with a highly efficient distributed system (e.g. point-of-use heat pumps tailored to varying temperature requirements), when they provide both cooling and heating and when they can reuse waste heat.

One of the challenges in assessing IHP potential in Australia is the lack of detailed information on heat requirements or waste heat availability. The only data on process heat in Australian industry includes assumptions that likely underplay the potential for substitution with IHPs, particularly in the F&B sector. Using results from detailed global studies, IEEFA found that the high energy losses likely in existing systems would mean IHPs could deliver energy savings of 80-90%, and therefore be highly financially attractive in the F&B sector. In the alumina sector, the use of waste heat means MVR could cut energy use by about 80%, only needing about 1GJ of electricity to replace each 5GJ of gas.

A key challenge for IHP deployment is their significantly higher upfront costs compared with conventional technologies. The global IHP market is expected to grow from US$2 billion in 2023 to US$11-US$21billion by 2030, bringing cost reductions. IHPs can deliver large operational cost savings through reduced energy use. Focusing on gas-based systems and using relative wholesale spot prices as a proxy in the absence of actual energy cost data, we found the electricity-to-gas price ratio has steadily decreased from 2015 to 2024, reaching about 2:1 in recent times. With such a ratio, IHPs could likely deliver energy cost savings of 36-75% compared with a traditional thermal system.

The infancy of the Australian market means there are few on-the-ground examples and very little public information on operational and financial performance of IHPs. A small number of government-supported feasibility studies and a real-life case study have found material energy and cost reductions in the F&B sector, with a range of productivity benefits, such as reduced maintenance costs and equipment downtime, as well as improved working conditions.

Heat pumps key to electric transformation

Electrification central to global energy and climate pledges

Efficient, flexible electrification is arguably the most important pillar of the energy transition, with the share of electricity in global energy consumption expected to more than double by 2050.[1] There are two primary reasons underlying the prominent role of electrification in the energy transition. Firstly, fossil fuel-based energy systems are inherently inefficient due to substantial losses in energy conversion (for example, turning primary energy inputs into secondary fuels or energy carriers) and delivery (transmission and distribution losses). Second, electric end-use technologies are typically far more efficient than fuel-based alternatives at converting delivered energy into useful services such as work (mechanical and electrical), heat and light.[2,3,4] These existing inefficiencies result in roughly two-thirds of global energy being wasted before its intended use.[5,6] Electric technologies powered by renewable energy sources can avoid many of these substantial losses while offering the prospect of complete decarbonisation.

Other factors also work in favour of electrification. For instance, digital and data-driven technologies expand opportunities for cost-effective energy system flexibility and optimisation, which will be increasingly valuable with higher proportions of intermittent wind and solar in the electricity generation mix.[7,8] These technologies offer particular energy and cost savings in the electricity sector by enabling demand-side response, virtual power plants, artificial intelligence and smart grid management.[9] Digitalisation allows electric systems to be integrated with advanced monitoring and control systems, enabling predictive maintenance, reducing downtime, and improving overall system performance.

Electrification can also enhance energy independence by reducing reliance on fuels such as gas, which can be subject to volatile prices and supply disruptions.[10] Finally, climate-related policies and pricing mechanisms improve the economic argument for electric technologies that produce no emissions when powered by renewable energy. The emergence of regulations such as Europe's

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[1] International Energy Agency (IEA). World Energy Outlook 2023. Figures 1.26 and 1.29, Announced Policies Scenario. Pages 59 and 66.

[2] IEA. Electrification. July 2023.

[3] Environmental Sciences Europe. Weiss, M., Cloos, K. C. & Helmers, E. Energy efficiency trade-offs in small to large electric vehicles. May 2020. Page 12. For example, electric vehicles are far more efficient (tank-to-wheel efficiency of 73-90%) than internal combustion engine vehicles (16-37%) over all relevant engine loads and speeds.

[4] US Department of Energy. 2018 Manufacturing Energy and Carbon Footprints: Definitions and Assumptions. December 2021. Page 9. Table 4 provides estimated process heating losses by industrial sector. Losses in end-use conversion of energy in industrial processes can range from 17-60% depending on sector.

[5] Pahud et al. Beyond primary energy: The energy transition needs a new lens. July 2023. Figure 6, Page 8.

[6] Lawrence Livermore National Laboratory. Energy Flow Charts | Flowcharts. Accessed 18 July 2024. Total losses of 67% calculated by comparing primary energy inputs with energy services.

[7] IRENA. Power system flexibility for the energy transition. Part 1: Overview for policy makers. November 2018. Pages 11-29.

[8] IEA. Digitalization & Energy. 2017. Pages 29-57 and 83-100.

[9] Business Finland. Digitalisation and electrification in symbiosis. March 2021. Pages 7 and 13-21.

[10] European Union. What if the EU were energy independent? December 2023. Page 2.

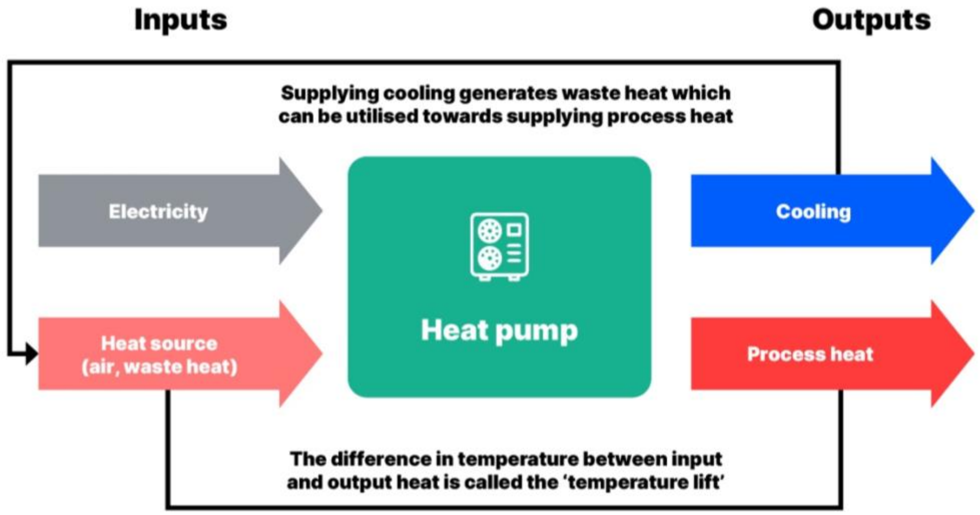
Climate Border Adjustment Mechanism[11] (CBAM) and subsidies in customer countries will likely add pressure on Australian industry to decarbonise.

This report focuses on heat pumps, which could be deployed in numerous sectors. Other electric technologies are also gaining wider application.[12]

IHPs can deliver large energy, emissions and cost reductions

Heat pumps are increasingly recognised as a critical technology in the global electrification transformation. A heat pump operates in the reverse manner of a refrigerator, by transferring heat from a colder area (heat source) to a warmer area (heat sink) by compressing a refrigerant to raise the temperature to a more useful level. Since most of the heat is transferred rather than generated, heat pumps are significantly more efficient than traditional heating technologies such as boilers or resistive electric heating, and they can be more cost-effective to operate. Typically, the energy output in the form of heat is several times greater than the energy required to power the heat pump, which is usually supplied by electricity.[13] This can result in efficiencies of 250-500%, and potentially even higher when heat pumps supply both heating and cooling.[14] In contrast, conventional heating options always have an efficiency below 100%, meaning they output less thermal energy compared with the energy input.

Figure 2: Heat pump inputs and outputs



Source: IEEFA

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[11] European Commission. Climate Border Adjustment Mechanism. 2024.
[12] Beyond Zero Emissions. Zero Carbon Industry Plan: Electrifying Industry. 2018. Pages 49-73.
[13] IEA. The Future of Heat Pumps. 2022. Page 18.
[14] Climact. Opportunities to get EU industry off natural gas quickly Cost analysis of alternatives to natural gas in food, chemical and glass industries. October 2022. Page 12.

The benefits of heat pumps for space cooling and heating and water heating are well understood in residential and commercial buildings, and they have experienced strong growth in recent years.[15] Heat pumps are expected to meet about 20% of global heating needs in buildings by 2030 and 40-50% by 2050.[16] In Australia, it is estimated nearly 14 million air conditioning units are used for both heating and cooling in homes, the vast majority of which would be heat pumps.[17] IEEFA analysis identified that installing gas-based and inefficient electric appliances instead of more efficient heat pump-based electric appliances is costing Australian households A$3.4 billion in unnecessary lifetime costs each year.[18]

However, industrial heat pumps (IHP) could also electrify a portion of process heat demand in industrial sectors, which is a major source of global energy demand and emissions. Compared with buildings, this potential is less well understood, and uptake has been limited, with heat pumps only supplying about 5% of global industrial heat. [19] In Australia, the market for IHPs is very immature, with only a handful of known projects.

The IHP market faces several challenges. Firstly, IHPs typically cost more upfront than gas boilers. However, depending on the relative price of electricity (to run the heat pump) and the fuel being displaced, the efficiency gains from IHPs can deliver cost savings and payback initial investments within a few years, offering attractive rates of return on investment and business productivity improvements.[20,21] Other barriers include a lack of awareness about the technology's capabilities and the potential complexity of integrating these systems into existing industrial processes.[22] There is a need for more demonstration projects and case studies to showcase the benefits and feasibility of IHPs. However, with increasing emphasis on energy efficiency and decarbonisation, there is significant potential for growth in this sector as more industries recognise the advantages of electrifying their process heat demand.

Technical potential and applicability of industrial heat pumps increasing

The technology landscape for IHPs is developing rapidly. Models capable of providing process heat up to 150°C have already been implemented in multiple commercial settings, with the vast majority supplying process heat of 50-100°C.[23,24] Temperature outputs beyond 150°C are possible but these

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[15] IEA. Global heat pump sales continue double-digit growth. 2023.

[16] IEA. The Future of Heat Pumps. 2022. Figures 1.7 and 1.12. Pages 26 and 32.

[17] Australian Government. Energy rating. 2021 Residential Baseline Study for Australia and New Zealand for 2000 — 2040. Output tables for Australia. November 2022.

[18] IEEFA. Appliance standards are key to driving the transition to efficient electric homes. April 2024.

[19] McKinsey. Industrial heat pumps: Five considerations for future growth. March 2024.

[20] A2EP. Renewable energy for process heat – Opportunity study phase 2 Final project knowledge sharing report. March 2022. Pages 32-33. Figures 26-29 present the impact of various factors on the payback periods for industrial heat pumps, such as capacity, heat lift and capacity factor.

[21] European Heat Pump Association (EHPA). Financing heat pumps – barriers and solutions. May 2024. Page 3.

[22] Energy Reports. Energy flexible heat pumps in industrial energy systems: A review. November 2022. Page 388.

[23] EHPA. Large scale heat pumps in Europe | Vol. 2. 2022.

[24] Renewable and Sustainable Energy Reviews. Large-scale heat pumps: Uptake and performance modelling of market-available devices. March 2021. Figure 2. This study assessed the operational performance of 425 operating points of IHPs from 10 manufacturers, all below 150°C. Three-quarters were found to operate within a "conventional" range with supply temperatures below 80°C, about one-fifth were considered "high temperature" with outputs of 80-100°C, with the remainder 100-150°C.

technologies are less efficient, and require special refrigerants and compressors not yet widely available.[25] There are a handful of small-scale heat pump applications beyond 150°C in settings with available high-temperature waste heat.[26] The International Energy Agency (IEA) maintains a list of the development level for different IHP technologies, which includes numerous commercially available options with supply temperatures ranging from 100-280°C (Table 1).

Along with temperature output, another key technical consideration for IHPs is the availability of suitable waste heat to be upgraded, which is a product of both quantity (energy content) and quality (temperature) that can vary considerably between different industrial processes. Ideally, the waste heat (source) and process heat demand (sink) should be close each other (preferably within the same process) of similar magnitude, and available within the same time period.[27] The temperature difference between heat source and sink, referred to as the temperature "lift", is a key constraint on IHP applicability, with most commercially available technologies limited to temperature lifts of 60-90°C (Table 1). However, cascaded or multi-stage heat pumps and multi-stage mechanical vapour recompression (MVR) can efficiently deliver larger temperature lifts by using the output heat of one stage as the input temperature to the next stage.

Table 1: Temperature capabilities of commercially available industrial heat pumps

Supplier	Max temp. supply	Max temp. lift	Capacity
Spilling	280°C	97°C	1-15MW
Piller	212°C	59°C	0.7-10MW
Epcon	210°C	24°C	0.2-100MW
Olvondo	200°C	147°C	0.5MW
Kobelco Compressors Corp.	175°C	64°C	0.8MW
Kobelco Compressors Corp.	175°C	115°C	0.4MW
Siemens Energy	160°C	103°C	8-70MW
AGO Energie	140°C	70°C	1-70MW
Ochsner Energie Technik	130°C	90°C	0.5MW
Mitsubishi Heavy Industries	130°C	75°C	0.5MW
Mayekawa (Eco Sirocco)	120°C	90°C	0.1MW
Kobelco Compressors Corp.	120°C	85°C	0.4MW
Combitherm	120°C	75°C	0.3-3.3MW
Fuji Electric	120°C	60°C	0.03MW
Mayekawa (EcoCircuit)	100°C	60°C	0.1MW

Sources: IEA, Heat Pumping Technologies. Note: Technologies presented are those assigned a Technology Readiness Level of at least 9, which indicates that the solution has achieved commercial operation in a relevant environment and is commercially available.

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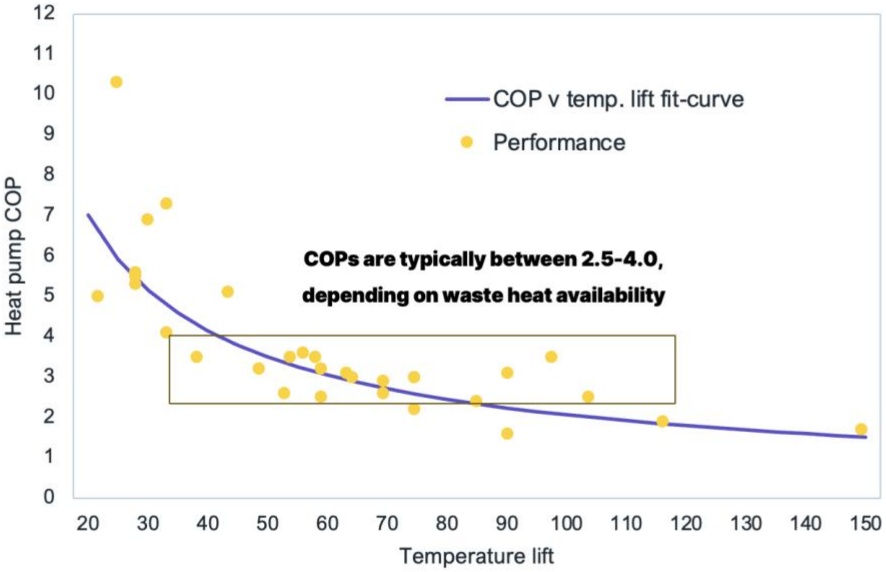
[25] Energy Efficiency & Conservation Authority. Industrial heat pumps for process heat. January 2023.
[26] IEA. The Future of Heat Pumps in China. March 2024. Page 65.
[27] Marina et al. An estimation of the European industrial heat pump market potential. April 2021. Page 4.

Heat pumps can deliver high efficiencies across a broad range of applications

Temperature lift is also a critical determinant of commercial viability given heat pump efficiency – known as the coefficient of performance (COP) – improves about 2-4% per degree of reduction in lift.[28] A heat pump's COP represents the amount of heat produced per unit of electricity input and can vary widely. The nascent state of the IHP market means there is limited information on real-world operating conditions and efficiencies of heat pump applications. While temperature lifts of close to 150°C are possible, existing IHP models operate most efficiently at lifts of 20-50°C, with large-scale examples in Europe (the most developed market) typically achieving COPs of 3-5 (i.e. efficiency of 300-500% in terms of energy output compared to electricity input).[29,30] If the efficiency gained from a specific temperature lift is not sufficient to counterbalance electricity prices (which are often higher than gas or coal prices), a heat pump is unlikely to be economically viable. An approximate relationship between temperature lift and COP is provided in **Error! Reference source not found.**, along with the stated performance of the commercially proven heat pump technologies from Table 1: Temperature capabilities of commercially available industrial heat pumps

. The COPs of these IHPs range widely, from 1.7-10.3, but predominantly 2.5-4. This is broadly consistent with other estimates that found COPs of 2.4-5.8 for temperature lifts of 40-95°C.[31]

Figure 3: Heat pump efficiency at different temperature lifts



Source: IEEFA. Note: Heat pump performance is based on supplier information provided in the IEA's Annex 58 database, for supplier technologies assigned a Technology Readiness Level of at least 9. There are two performance metrics plotted for each model where

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[28] A2EP. High temperature heat pumps for the Australian food industry: Opportunities assessment. August 2017. Page 6.
[29] IEA. The Future of Heat Pumps in China. March 2024.
[30] EHPA. Large scale heat pumps in Europe | Vol. 2. 2022.
[31] Energy. High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials. June 2018.

data was available, covering the high/low COP range. The COP fit-curve is based on the equation provided in Slide 5 of Dr Cordin Arpagaus's presentation in February 2023.

The importance of minimising temperature lift means the availability of sufficiently high-temperature waste heat sources is another critical factor in IHP applicability and economic viability. There are many widely available, low-temperature waste heat sources in industrial systems suitable for IHPs, including exhaust gases, cooling water, washing systems, air compressors and chillers.[32,33] Low-temperature heat pumps can also use ambient air to reach 60-65ºC, and are typically available as generic, off-the-shelf products.[34] As a result, global studies have found significant heat recovery potential for IHP applications. For example, an assessment of IHP market potential in the EU estimated waste heat sufficient to cover 73% of process heating needs below 150°C, with the majority of this waste heat below 60°C, while a French study identified more than 100% coverage potential in some sectors, including food and beverages.[35,36] This potential could be higher if additional heat were sourced from neighbouring industrial facilities or if some processes were modified to run on lower temperatures.[37] However, the availability of waste heat in Australia's industrial systems remains poorly understood, mostly owing to a lack of available data.

Anticipated IHP technological developments in the coming decade could deliver even higher supply temperatures, higher temperature lifts and improved efficiencies.[38,39,40] There is potential to use multiple heat pumps in series (cascading or multi-stage), where the heat output from one unit provides input for a second unit. This approach can enable units to operate across larger overall temperature differences at high efficiencies, though they are more complex and expensive.[41] Notably, using heat pumps to store heat for later use can achieve high temperatures, efficiencies and flexibility. Other emerging opportunities include creative sourcing of industrial heat, and "boosting" heat pump output using resistive heaters or other technologies.[42]

Global IHP market expected to boom

Heat pumps are expected to play a large role in industrial decarbonisation plans, particularly in sectors with low temperature requirements (for example, under 150°C). The European Union (EU)

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[32] BCS. Waste Heat Recovery: Technology and Opportunities in US Industry. March 2008. Page 8. Table 4.

[33] Hita et al. Assessment of the potential of heat recovery in food and drink industry by the use of TIMES model. June 2011. Page 738.

[34] NZ Government. Energy Efficiency and Conservation Authority (EECA). Industrial heat pumps for process heat Information for businesses looking for low-carbon alternatives to fossil-fuelled boilers. January 2023.

[35] Renewable and Sustainable Energy Reviews. An estimation of the European industrial heat pump market potential. April 2021. Pages 10-11. Table 4. This study assessed four sectors most suitable for IHP applications: paper and pulp, chemicals, food and refineries. Figure 6 provides an estimate of waste heat potential by temperature.

[36] EDF R&D. The heat recovery potential in the French industry: which opportunities for heat pump systems? 2009. Page 1122. Table 8.

[37] IEA. The Future of Heat Pumps. 2022. Page 38.

[38] Rightor et al. Industrial Heat Pumps: Electrifying industry's process heat. March 2022.

[39] IEA. The Future of Heat Pumps. 2022.

[40] Fraunhofer ISI. Direct electrification of industrial process heat. An assessment of technologies, June 2024. potentials and future prospects for the EU. June 2024. Page 26. Table 3 notes potential upper limit of 300°C by 2035.

[41] A2EP. High temperature heat pumps for the Australian food industry: Opportunities assessment. August 2017. Page 6.

[42] Consultation with energy efficiency expert Alan Pears, senior industry fellow at RMIT.

represents more than half of the global IHP market, reflective of the region's leadership on industrial decarbonisation policies and investment.[43] For example, the Energy Efficiency Directive sets a reduction target of 12% in total energy consumption by 2030 relative to a 2020 baseline, while a recently adopted Renewable Energy Directive also supports adoption of IHPs.[44,45] About 40% of the EU's industrial process heat is below 200°C, where IHPs could deliver cost-effective heat.[46] In the US, it is estimated that IHPs could address 29% of industrial thermal energy use, with particular applications in the food, paper and chemicals sectors, alongside a potential role in electrifying process heat in oil refineries.[47]

The global IHP market was worth US$2 billion in 2023 and is expected to grow by more than 15% a year until 2030, driven in particular by deployment in Asia and Europe. This means the IHP equipment market could be worth US$11-21 billion by 2030, with about 40% of the opportunity coming from China.[48]

IHP viability hinges on a range of site factors

Economic case for – and challenges to – industrial applications

There is no one-size-fits all solution for industrial process heating. While there may be a theoretical opportunity for heat pump deployment based on process temperature requirements, there are a range of site- and region-specific factors that will determine technical and commercial viability. To meet process needs, large-scale heat pumps may also need to be customised as they often require specific considerations for power output, utilisation rates and the temperature levels of both heat sources and sinks.[49] Key facility factors include:

- Temperature requirements for heat;
- Temperature lift from available heat;
- Lifespan of assets;
- Capacity factor and timing of heat usage;
- Space limitations (for example, availability of land or roof space);
- Ease of integration with existing infrastructure;
- Cost of fuel sources; and
- Access to renewable energy resources.

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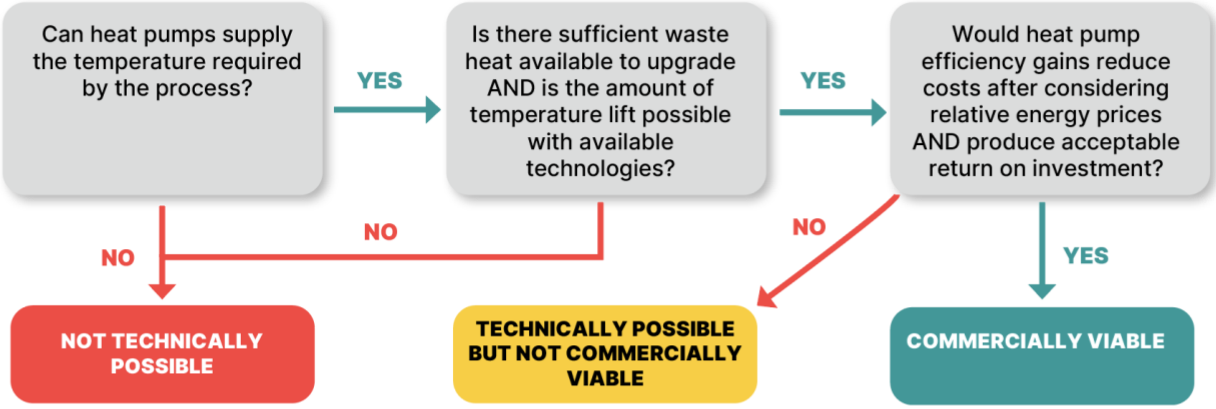
[43] Beyond Zero Emissions. Heat pumps supply chain. February 2024. Page 8.
[44] European Commission. New Energy Efficiency Directive published. September 2023.
[45] European Commission. Renewable Energy Directive. October 2023.
[46] IEA Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP). High-Temperature Heat Pumps Provide the Necessary Decarbonization. Accessed 18 July 2024.
[47] Renewable Thermal Collective. Industrial Thermal Decarbonization Package. Pages 14 and 34.
[48] McKinsey. Industrial heat pumps: Five considerations for future growth. March 2024. Exhibit 1.
[49] Ibid.

Conventional boiler systems are often oversized for peak demand, increasing heat losses. However, thermal storage allows IHPs to be sized to instead meet average load and deliver the same energy services with as little as half the capacity.[50] Combining heat pumps with thermal storage creates additional opportunities for flexible operation and the provision of demand response services, particularly for manufacturing sites that produce goods in batches.[51]

The first step in evaluating the suitability of IHPs is to ensure they are technically capable of meeting the requirements of the industrial process being assessed. This involves determining if the required process temperatures are achievable, and if the required temperature lift is within the range of available heat pump technology. The required process temperature should not be mistaken for the present supply temperature as it is often much lower, as discussed below.

Once technical feasibility is established, more detailed financial analysis can be undertaken. The economic viability of an IHP application will largely depend on the performance of the heat pumps, the losses in existing thermal energy systems, and the price of electricity relative to the fossil fuels used for combustion, typically gas (Figure 4).

Figure 4: Simplified screening process for industrial heat pump viability



Source: IEEFA

In general, the economics of heat pumps improve with:

- Decreasing efficiency of competing thermal energy systems;
- Lower costs of electricity relative to fuels such as gas, including consideration of lifetime carbon costs; and

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[50] A2EP. Renewable energy for process heat – Opportunity study phase 2. March 2022. Pages 11 and 34-35.

[51] World Business Council for Sustainable Development (WBCSD). Industrial Heat Pumps: It's time to go electric. September 2022. Page 21.

- Increasing heat pump efficiency (which is mostly a product of temperature needs and waste heat availability).

The Australian Alliance for Energy Productivity (A2EP) has developed a Heat Pump Estimator tool to aid planning for industrial and commercial heat pump projects. It computes costs, energy savings and payback period based on numerous variables.[52]

Market trends are also improving the business case for heat pumps, particularly declining electricity-to-gas price ratios, customer and policy pressure to decarbonise operations, and increasing costs of carbon.[53] Renewable electricity power purchase agreements, onsite renewable generation and high adoption of rooftop solar mean electricity prices can be low at times, so demand flexibility can enhance the economics of heat pumps. The most attractive cases for IHPs combine heating and cooling demand because they maximise energy efficiency, cost savings and space optimisation by utilising waste heat from cooling for heating purposes and enhancing process integration and reliability. This could drive improved returns on investment, particularly in industries such as F&B given the frequent need for simultaneous heating and cooling services, and the importance of temperature control.[54,55]

Tracking losses in thermal energy systems essential

Once a heat pump is technically able to displace fossil fuel in an industrial process, a key determinant of commercial viability is the ratio of electricity price to fuel prices together with the energy conversion efficiency of the competing processes.[56] The price and efficiency of gas is the most relevant fuel to consider given it produces most of Australia's process heat.[57]

As discussed, conventional energy supply systems involve large amounts of waste. Losses occur at various stages, from energy production, conversion (at the end-use technology), transmission and distribution. As a result, the overall system efficiency of heating processes is generally much lower than 80%, and it may be as low as 30% in some cases. Steam distribution systems are particularly inefficient due to heat dissipation, leakage of steam traps, lack of condensate recovery, and other factors depending on the quality of the insulation and the length of the distribution network.[58] In Australia, further inefficiencies seem to stem from process heat being supplied at temperatures that are higher than required by industrial processes.[59] This is likely perpetuated by historic access to cheap fuels that favoured centralised systems, and underinvestment in overall delivered energy

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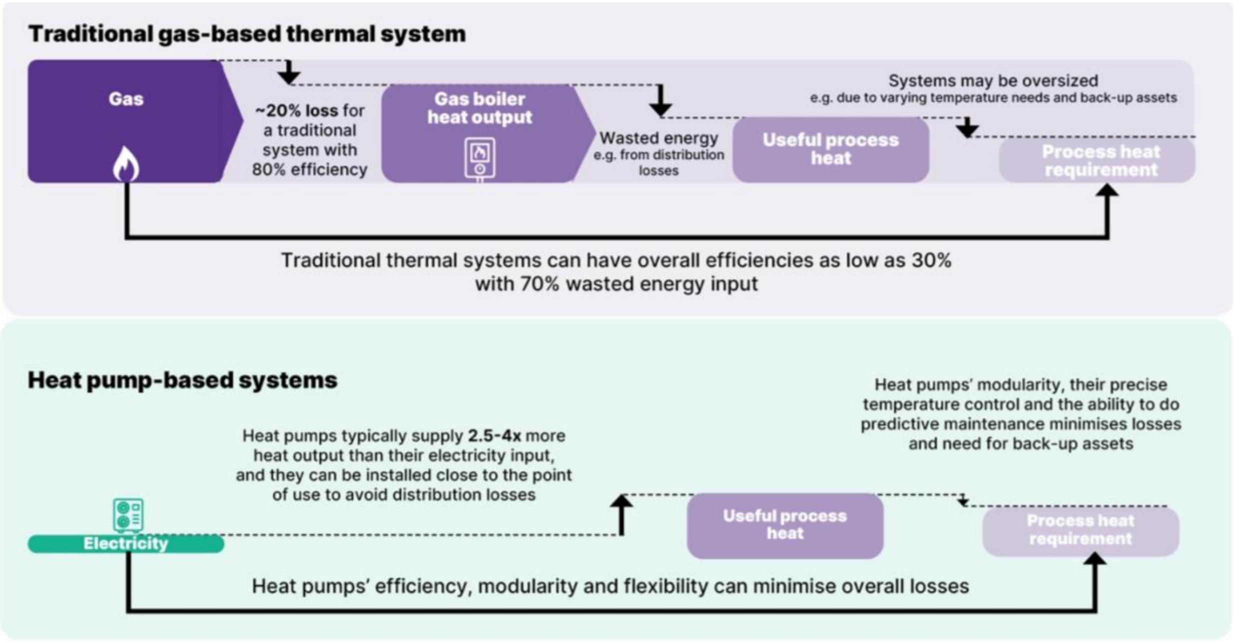
[52] A2EP. Heat Pump Estimator. 2024.
[53] WBCSD. Industrial Heat Pumps: It's time to go electric. September 2022. Page 3.
[54] CIMCO. Decarbonizing Food Processes with Industrial Heat Pumps. 2024.
[55] Julabo USA. The Importance of Liquid Temperature Control in the Food and Beverage Industry. April 2024.
[56] Australian Renewable Energy Agency (ARENA). Renewable energy options for industrial process heat. November 2019. Page 71.
[57] Ibid. Page 30.
[58] Expert consultation with Alan Pears.
[59] Based on the fact that temperatures supplied to Australia's industrial processes are generally higher than what is typically required based on global research and expert consultation.

efficiency.[60] Poor monitoring means many businesses may not know the real efficiencies of their energy systems.

IHPs offer a modular and flexible alternative with higher efficiency. This means IHPs can be installed closer to the point of use, minimising distribution losses, and eliminating the need for extensive heat distribution networks. Heat pumps also offer the advantage of precise temperature control, which is particularly important in applications requiring specific temperatures for product quality and process efficiency.[61] This adaptability enables a spectrum of temperature-control solutions to optimally match heat supply to specific process requirements, rather than like-for-like replacement of systems that utilise a single, centralised boiler delivering heat at one temperature.[62]

Figure 5: Energy losses in gas-based thermal system vs heat-pump based system



Source: IEEFA

IHPs powered by renewables could deliver process heat with 68-90% less energy

Accounting for losses in thermal energy systems enables an accurate comparison of the delivered heat efficiencies of heat pumps versus conventional technologies (Figure 5). For example, an IHP with a COP of 2.5 uses 68% less energy than a gas-based system with 80% efficiency. At lower temperature lifts (achievable through lower-temperature process heat requirements and/or higher-

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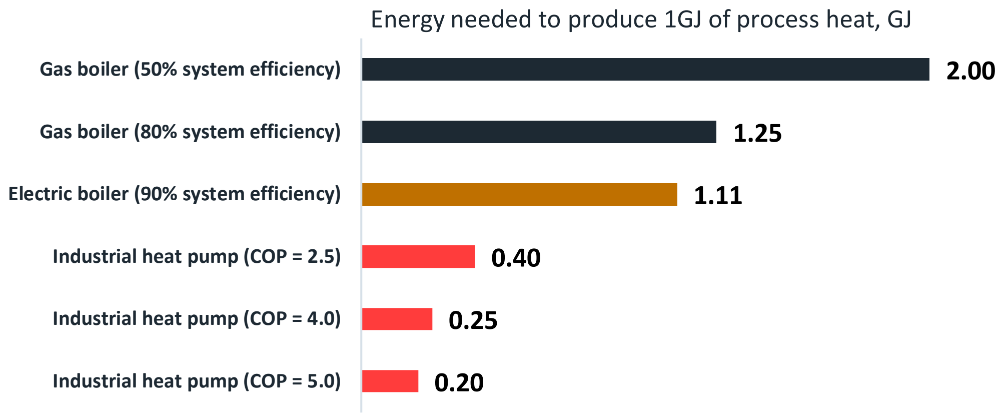
[60] A2EP. High temperature heat pumps for the Australian food industry: Opportunities assessment. August 2017. Page iv.
[61] OCOsink. Industrial Heat Pumps: The sustainable choice for modern manufacturing. October 2023.
[62] A2EP. Renewable energy for process heat – Opportunity study phase 2. March 2022. Page 11. For example, a process plant with varying heat demands may best be served by: an air-sourced heat pump for 65°C hot water washing; a water-sourced heat pump using waste heat from a refrigeration plant could supply 85°C heating for pasteurisation and; another technology for 150°C heating in a cooking process.

temperature waste heat availability), a COP of 5 could feasibly be achieved. Such an IHP system would require 16% the energy of a gas system with 80% efficiency, and 10% compared with a gas system with 50% efficiency. This means that across a COP range of 2.5-4, IHPs can likely deliver energy savings of at least 68-90%. Based on research discussed throughout this report, the relative efficiencies in Figure 6 are considered plausible given the losses associated with traditional thermal energy systems, temperature requirements of certain industrial sectors, and potential waste heat available in Australian facilities.

Figure 6: Gas boilers vs industrial heat pumps by efficiency of delivered heat



Sources: IEEFA analysis, ARENA, A2EP. Note: Lower bound of a 50% gas system efficiency is conservative based on IEEFA research (for example, see the US Department of Energy's Energy and Carbon Footprint assumptions, Table 4) and may be lower in some settings. Upper bounds of 80% aligned to conversion efficiency assumption in ARENA's 2019 report. IHP COP examples illustrate a plausible and technically feasible range of temperature lifts based on IEEFA analysis. The COP values corresponding to these temperature lifts are derived from a fit-curve provided by Dr Cordin Arpagaus.

Relative price of electricity and existing fuels key to IHP competitiveness

Along with the relative efficiencies of technologies discussed above, other key factors in IHP economic performance are the electricity-to-fuel price ratio, heat pump capacity, utilisation rate and the portion of boiler load being replaced. This report focuses on shifting gas-based process heat to electricity, given gas is the dominant fuel used to supply process heat, and likely to be the most cost-effective fuel to electrify. This section assesses recent trends in gas and electricity prices and the impact on the electricity-to-gas price ratio (EGPR).

Energy prices are commercially sensitive and typically not reported publicly, making it difficult to estimate the average price paid by industrial users and the potential cost savings from switching to IHPs. Industrial energy contracts are also complex and highly dependent on the volume and location of use, and whether a consumer is a retail customer or dealing at the wholesale level. Larger gas users, including many industrial facilities, generally purchase wholesale gas direct from gas producers under longer-term contracts, or gas supply agreements (GSAs), which specify price and delivery terms.[63] About 90% of gas in the east coast market is supplied under such contracts, with the remainder sold through short-term spot markets.[64] Smaller facilities (those using less than 100,000 gigajoules (GJ) of energy a year) typically pay gas prices close to full domestic retail costs: potentially three to four times higher than wholesale prices available to large users.[65] These dynamics also broadly apply for electricity, where the very largest users may connect directly to the electricity transmission system, and are likely to pay close to the average wholesale price. However, there is scope to use “behind the meter” electricity generation, time-variable electricity pricing, power purchase agreements and (thermal and battery) storage to reduce electricity costs.

From 2016 to 2020, quantity-weighted average prices under new gas supply agreements (GSAs) for east coast commercial and industrial buyers with an annual quantity of 500,000GJ or more were relatively flat.[66] However, since 2020, those have nearly tripled to about $20/GJ. Average wholesale gas spot prices for Victoria, New South Wales, Queensland and South Australia have also increased significantly, increasing 2.6-fold between 2014 and 2024, even when excluding the impacts of a severe gas price spike in 2022 and 2023.[67] Since 2016, weighted-average annual gas spot market prices have been lower than prices agreed under GSAs.

No public data is available on average electricity prices paid by large industrial energy users, relative to GSAs averages. The weighted-average electricity spot market across Australia’s National Electricity Market (NEM) has experienced similar volatility and price growth to the east coast gas market. Prices from 2022 to 2024 were $86-133/MWh (or $24-37/GJ), 1.6-2.4 times higher than 2014. The fact gas spot prices have experienced a greater relative increase than electricity spot prices over this period suggests a decoupling of gas and electricity prices that have historically been highly correlated.[68] This coincided with a material decrease in gas-powered generation.[69] As gas-powered electricity generation decreases and renewable uptake increases in the NEM, this trend may continue, improving the economic case for electric technologies.

Without knowing the average gas and electricity price paid by industrial users in different sectors, it is challenging to calculate an EGPR that can be used for detailed financial analysis of IHPs. Figure 7 presents an indicative EGPR based on wholesale gas and electricity spot market prices, given this data is comparable, and available for the same locations and time periods. This shows that the weighted-average wholesale spot price of electricity relative to gas has continually declined, roughly halving overall since 2014, suggesting an EGPR of about 2 across the NEM, and potentially as low as 1.7 in Victoria. In the absence of more detailed data for industrial users, we consider EGPRs of 1.5-3 are plausible for Australia in this analysis.

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[63] Energy Quest. Fact Sheet: Spot and contract markets and prices. 2024. Page 1.

[64] Australian Government. Department of Climate Change, Energy, the Environment and Water (DCCEEW). Fact sheet: Design of the Gas Market Code. July 2023. Page 4.

[65] ARENA. Renewable energy options for industrial process heat. November 2019. Page 34.

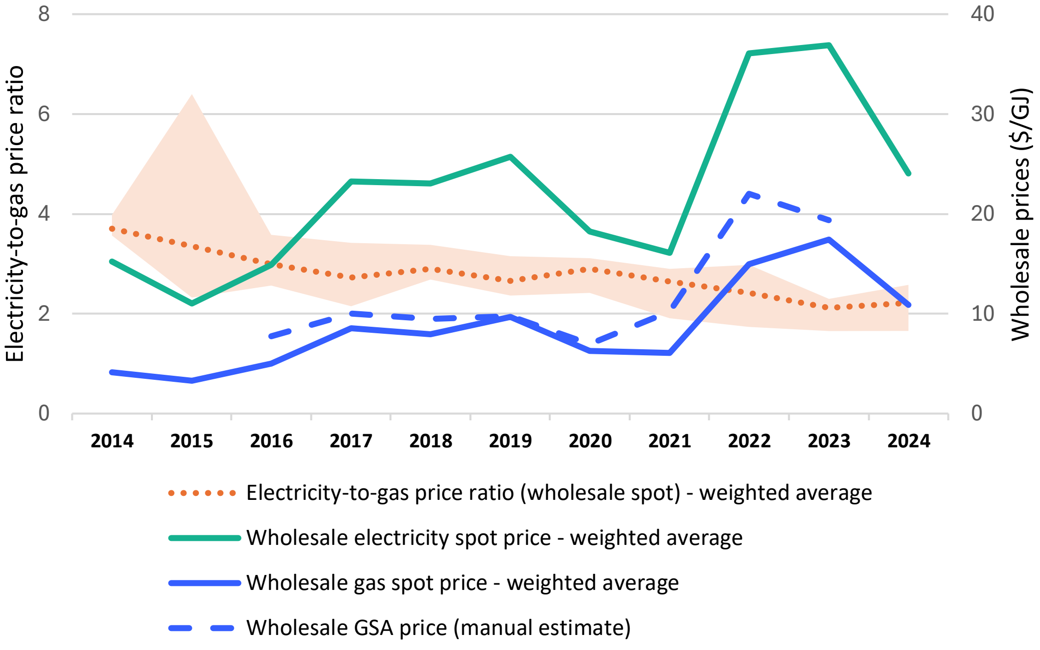
[66] Australian Competition and Consumer Commission (ACCC). Gas Inquiry 2017-2030. 2024.

[67] Australian Energy Regulator (AEMO). Gas market prices. 2023.

[68] Australian Energy Market Operator (AEMO). Quarterly Energy Dynamics Q2 2022. July 2022. Page 16. Figure 17.

[69] Australian Energy Regulator (AER). Average daily gas used for gas powered generation. 2024.

Figure 7: Relationship between Australia's wholesale gas and electricity prices



Sources: IEEFA analysis, AER, AEMO, ACCC. Note: Illustrative only given regional variability and inconsistent data availability. Wholesale gas prices based on the AER register, as of 1 April 2024. Wholesale electricity prices based on annual average prices in AEMO's National Electricity Market data dashboard. A weighted average price was calculated based on prices and share of national consumption in NSW, QLD, VIC and SA based on Australian Energy Statistics. GSA prices for a particular year were estimated based on prices agreed for commercial and industrial users on the east coast, available in ACCC interim reports.

Return on investment can offset IHPs' higher upfront costs

A key challenge for IHP deployment is the significantly higher upfront costs compared with conventional technologies. Estimates vary, but IHP capital costs are generally three to four times higher than new gas or electric boilers.[70,71,72] However, this is expected to improve as the global IHP market scales up. The economic feasibility of IHPs depends on the ability to produce sufficiently large operational cost savings to overcome these relatively high capital investment requirements. Under the right conditions (particularly with low temperature lifts), IHPs can have payback periods of less than two years, although in other cases this can exceed five years.[73,74]

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[70] NZ EECA. Industrial heat pumps for process heat Information for businesses looking for low-carbon alternatives to fossil-fuelled boilers. January 2023.

[71] Climact. Opportunities to get EU industry off natural gas quickly Cost analysis of alternatives to natural gas in food, chemical and glass industries. October 2022. Page 12.

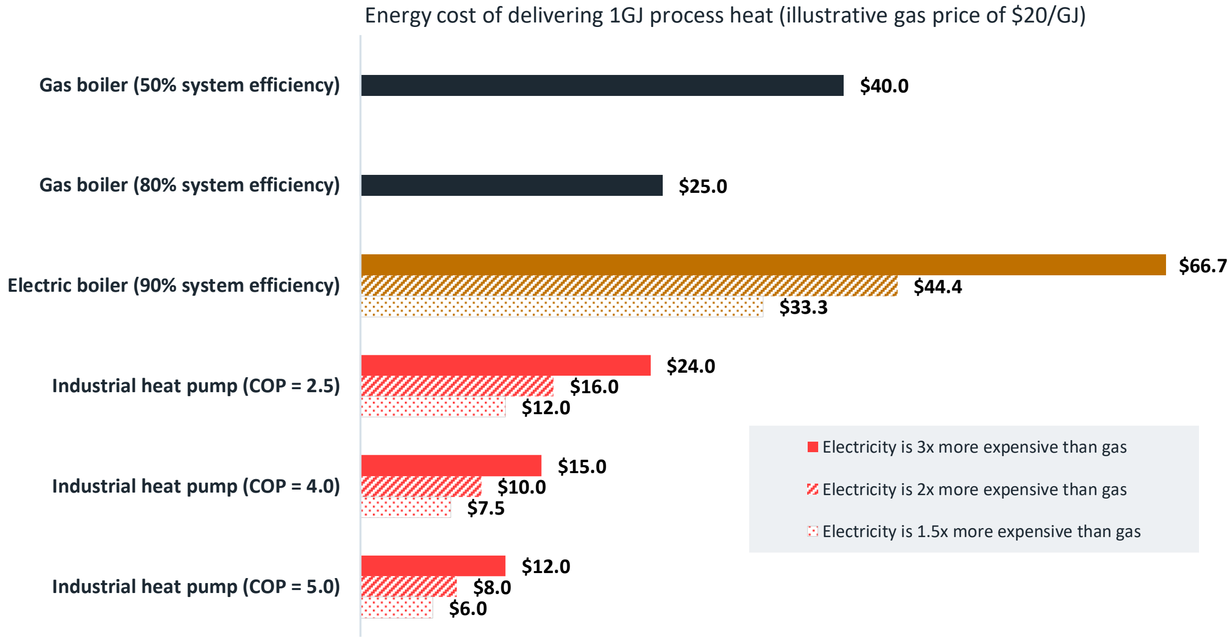
[72] Energy Innovation Policy & Technology. Decarbonizing Low-Temperature Industrial Heat in the US. October 2022. Page 16.

[73] Energy Conversion and Management. Techno-economic analysis of high-temperature heat pumps with low-global warming potential refrigerants for upgrading waste heat up to 150°C. December 2020.

[74] Rightor et al. Industrial Heat Pumps: Electrifying Industry's Process Heat Supply. March 2022. Page 13. Table 2.

The impact of EGPR when combined with relative efficiencies of competing technologies for process heat is provided in Figure 8. An IHP with a COP above 3 is likely to offer energy cost savings across a range of EGPRs relative to a gas-based system with an assumed 80% efficiency. Naturally, the cost of delivered energy declines with a lower EGPR and greater relative efficiencies of IHPs to conventional systems (through a higher COP and/or greater assumed losses in fossil fuel-based systems). With an average EGPR of 2, an IHP would likely deliver energy cost savings of 36-75%.

Figure 8: Gas boilers vs industrial heat pumps by relative energy costs of delivered heat



Source: IEEFA. Note: Illustrative system efficiencies use electricity-to-gas price ratios.

The infancy of the Australian IHP market means there are few on-the-ground examples and very little public information on their operational and financial performance. To fill this knowledge gap, the Australian Alliance for Energy Productivity (A2EP) launched the Renewable Energy for Process Heat Opportunity Study in 2019. Supported by A$2 million of Australian Renewable Energy Agency (ARENA) funding, this initiative sought to determine the technical and commercial feasibility of replacing fossil fuel-based process heating technologies in Australian manufacturing with renewable-powered alternatives, and detail pathways to implementation. It assessed various renewable heating methods, including IHPs, and produced 20 pre-feasibility and seven feasibility studies across food and beverage and other industries (Table 2).

In 2022, the A2EP found all projects with heat demand below 90°C selected heat pump technologies that had typical payback periods of five to six years and some as low as two years.[75] This is consistent with other global studies, highlighting the applicability of IHPs for cost-effective electrification in sectors with low temperature process heat requirements.

Table 2: Identified project benefits from feasibility studies

Project (company)	Financial metrics and other benefits
Winery (De Bortoli)	Capital cost: $950,000 Energy cost savings: 11.2% Energy reduction: 28.6% Fossil fuels reduction: 86.0% Facility emissions reduction: 8.6% Payback period: 4.8 years Productivity benefits: cooling tower water savings, reduced maintenance costs, reduced plant downtime/increased plant reliability, improved refrigeration efficiency.
Brewery (Lion)	Capital cost: $3,430,000 Energy cost savings: 24% Energy reduction: 32% Facility emissions reduction: 27% Payback period: 4.4 years Productivity benefits: reduced boiler standby losses, reduced maintenance, greater ability to respond to partial loading of production levels, reduced run times of refrigeration equipment.
Brewery (3 Ravens)	Capital cost: $220,000 Energy cost savings: $33,800 a year Energy reduction: 76% Facility emissions reduction: 27% Payback period: 6.5 years Other benefits: increased comfort and improved facility ventilation, reduced liability climate-damaging refrigerants, enhanced brewing automation, increased throughput.

Source: A2EP

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[75] A2EP. Decarbonisation with industrial heat pumps: Policy & program update from Australia. April 2022. Page 13.

Case study 1: Meat processing facility[76,77]

A leading example of successful IHP deployment is Hardwick Processors (now owned by Kilcoy), a meat producer based in Victoria. This project commenced as a feasibility study to investigate installing a 1 megawatt (MW) thermal capacity heat pump, along with heat recovery infrastructure, to deliver hot water at 75°C and displace 75% of the plant's gas usage. The study found it would be most efficient to run a smaller and less expensive heat pump continuously, storing hot water in existing thermal tanks. Substantial electricity infrastructure upgrades and enhancements to an existing microgrid system were also required. Among the benefits identified during the study were a 44% decrease in overall energy consumption, 22% reduction in facility emissions and 16% net energy cost savings.

Since being commissioned, the project's financial performance has surpassed expectations due to higher-than-anticipated gas costs, potentially reducing the payback period to about two years (compared with the original five-year estimate). Additional productivity benefits include reductions in water consumption, condenser fan power and chemical use, and avoided additional costs for condenser capacity and boilers.

The heat pump operates continuously during weekdays, and supports batch cleaning cycles on weekends, with hot water stored in two 160,000-litre thermal tanks. The stable operation of the heat pump has enhanced its reliability and efficiency, with thermal storage smoothing heating demand, improving control and efficiency. This has enabled the heat pump to satisfy the heating load with half the capacity of the 2,000 kilowatt (kW) boiler being replaced.

Following this project's success, the company is considering installing a second heat pump integrated with renewables, along with additional thermal storage to enable load shifting to manage tariffs and participate in demand-response programs.

IHPs an underutilised opportunity in Australia

Better data needed to understand financial potential

Understanding the potential for heat pumps to address Australia's process heat requires detailed information on each of the factors discussed in the previous section. Unfortunately, there is no sector-, process- or facility-level information on process heat requirements or waste heat availability in Australian industry. This poor data availability may partly explain the lack of attention on this area.

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[76] Hardwick Processors. Heat Pump Project: Project Knowledge Sharing Report (Interim). April 2023.
[77] A2EP. Renewable energy for process heat – Opportunity study phase 2. March 2022. Page 23.

A 2019 report prepared for ARENA is the most comprehensive account of Australia's industrial process heat, but methodological limitations mean this may understate the potential for electric technologies such as heat pumps.

This study implies that 9% of industrial process heat supply is below 150°C, and just under half below 250°C. However, these temperature categorisations are based on boiler output temperatures rather than those actually required by the end use, which are likely materially lower.

Total process heat demand is also estimated by applying a standard 80% conversion efficiency to estimated fuel (primary energy) used for heat production in each sector, rather than bottom-up calculations from individual processes. This is an optimistic view of the relationship between primary energy use and heat demand, given energy supply inefficiencies discussed elsewhere in this report. For comparison, process heating losses in US manufacturing sectors are estimated at 17-60%, with a weighted average of 33%. This is equivalent to an industry-wide average efficiency of 67% and as low as 40% in some sectors. Applying an industry-wide efficiency factor may produce estimates within an acceptable error range at the overall level or for sectors that combust fuel directly for heat. However, this likely fails to capture the potentially significant losses in steam production and distribution systems used extensively in industrial sectors such as food and beverages (discussed further below). The result understates the amount of waste in thermal energy systems and potentially overstates the heat demand in some sectors. [78]

These assumptions are critical for assessing the potential business case for IHPs, given relative efficiencies of competing technologies are a key driver of energy costs. Such uncertainty could result in a considerable underestimation of the proportion of Australia's industrial heat able to be cost-effectively supplied by electric technologies such as IHPs. A key risk for businesses and climate policy is that if real-world gas efficiencies are significantly lower than typical assumptions, the overestimation of high-temperature heat requirements would result in underinvestment in IHPs and overly optimistic estimates of demand for hydrogen and other high-temperature industrial heat sources.

Furthermore, the low capital cost, precision and flexibility of some direct electricity use technologies, combined with potentially low renewable electricity prices, may not be adequately considered in Australian policies and business decision-making. This includes combinations of IHPs and "boosting" with direct electric equipment, utilisation of waste process heat, and utilisation of "cold" from heat pumps.

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[78] ARENA. Renewable energy options for industrial process heat. November 2019. It notes, "after allowing for distribution and other losses, some steam applications may have an end use efficiency of 50% or less" but this does not appear to be accounted in the sectoral analysis.

Large gas and cost savings attainable in food and beverage

The food and beverage (F&B) sector is frequently highlighted as an immediate opportunity for IHP deployment given that most of the heat required for these processes is at low temperatures. Global studies suggest 83-97% of process heat in the sectors is below 150°C, within the technical capabilities of commercially available IHPs.[79,80,81] In comparison, the ARENA report suggests that 39% of process heat in Australia's F&B sector is below 150°C, with a further 46% below 250°C.[82]

As discussed earlier, the difference is largely explained by the fact that the temperature categories in this report are based on boiler output temperatures rather than process requirements. Assuming global studies better represent the temperature required by F&B processes, IEEFA considers that IHPs with temperature outputs below 150°C could satisfy at least 85% of heat demand in Australia's F&B sector.

Steam is also widely used in F&B sector, likely resulting in less efficient energy supply systems (as discussed earlier) compared with other sectors. In the US, F&B process heat losses are estimated at 55% (equivalent to an efficiency of 45%), considerably higher than in most other manufacturing sectors.[83] Assuming a system efficiency of 45% rather than 80% for Australia's F&B sector drastically reduces total heat demand from 27PJ to 15PJ. In other words, there is about three times more energy waste in a system with 45% efficiency compared with one with 80%.

While detailed information on energy flows in Australia's F&B sector is lacking, there is no reason to believe process heat requirements and supply efficiencies would materially differ from regions such as the US or EU.

Figure 9 compares estimates of gas use for process heat in Australia's F&B sector with updated estimates that have been aligned to international data.

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[79] Applied Thermal Engineering. Estimating the potential of industrial (high-temperature) heat pumps for exploiting waste heat in EU industries. June 2019. Figure 2 suggests about 83% of process heat needs in the EU are below 150°C, and 12% below 250°C.

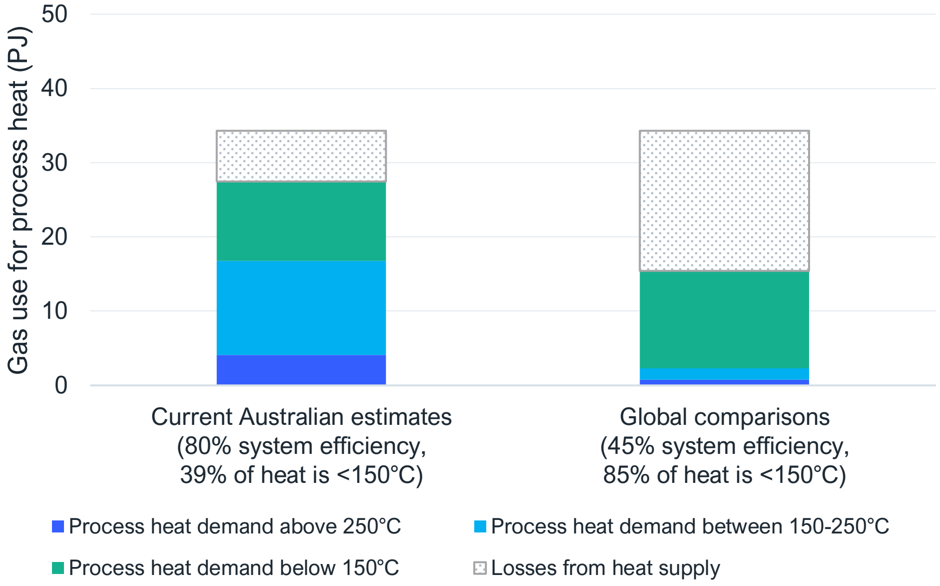
[80] American Council for an Energy-Efficient Economy (ACEEE). Industrial Heat Pump Market Transformation. 2023. Page 5. In the US, nearly all the process heat in food and beverage sectors is below 150°C (roughly half below 80°C and half above 80°C).

[81] Renewable Thermal Collaborative. Renewable Thermal Vision report. Food and Beverage Sector Pack: "97% of industrial heat needs are for applications is in the low temperature range (<130ºC), which can be decarbonized on an accelerated timeline with electrification and heat pumps."

[82] ARENA. Renewable energy options for industrial process heat. November 2019. Page 29.

[83] US Department of Energy. 2018 Manufacturing Energy and Carbon Footprints. December 2021. Page 9. Table 4.

Figure 9: Gas savings in food and beverage sector by heat demand scenario



Sources: IEEFA analysis, ARENA. Note: Left column shows estimates of food and beverage process heat from the ARENA report (Table 1). Total process heat demand is calculated by applying an 80% conversion efficiency to estimated fuel used for produce heat. Temperature categories are based on current boiler output. Right column applies a 45% conversion efficiency (in line with the US food and beverage sector), and temperature categorisations based on global studies.

In short, aligning heat requirements to global comparisons implies both a much higher proportion of Australia's F&B sector could switch to IHPs with available models, and the energy savings would be much higher due to avoided waste. It suggests IHPs could eliminate 29PJ of gas use for heat below 150°C in the sector, equivalent to about 2% of Australia's annual consumption. It also suggests IHPs could deliver energy savings of 80-90% in this sector.

IHP advancements could replace up to 17% of Australia's gas use

Process heat in Australia's industrial sectors is mainly produced through the combustion of fossil fuels and is responsible for about 15% of annual primary energy use.[84] Just under half of the fuel used to produce industrial process heat is gas. This report focuses on the opportunity to shift from gas-based heating systems to IHPs, given it is likely to be the most financially viable.

Figure 10 shows the estimated gas use that can be electrified by IHPs, based on data from the ARENA report and analysis by IEEFA. The potential in the F&B sector represents the result of global alignment as per the previous section. It includes all gas use to supply process heat up to 250°C.

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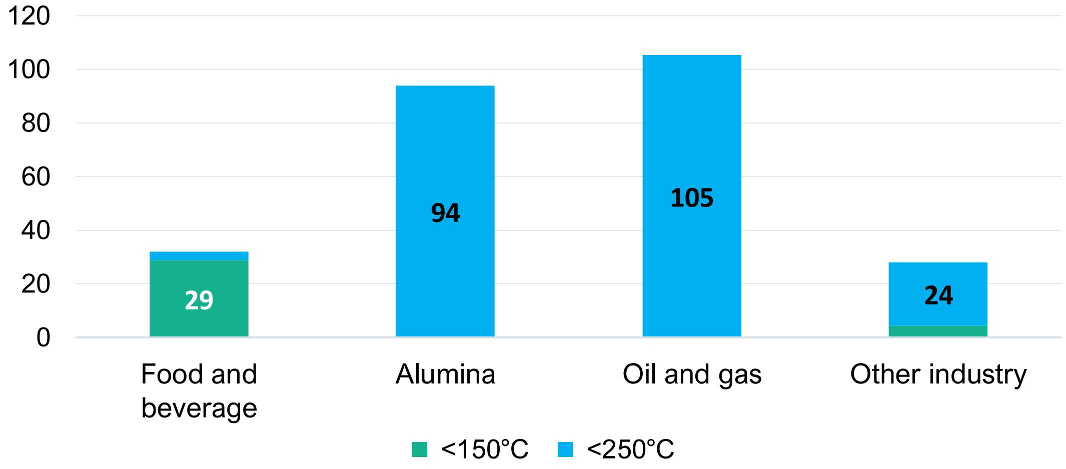
[84] ARENA. Renewable energy options for industrial process heat. November 2019. Page viii. Final energy used for process heat compared with total energy use from Australian Energy Statistics.

This accounts for the fact that end-use temperatures outside the F&B sector may also be lower than those supplied (especially in steam-based systems), along with the potential for higher IHP output temperatures towards 250°C in coming years. The potential in alumina is based on sector-specific analysis explained below.

This would mean IHPs could replace more than half of the roughly 450PJ of gas likely used for industrial process heat, or about 17% of Australia's gas use.[85] The most likely opportunities are in the F&B, alumina and other light manufacturing sectors, where replaceable gas represents 10% of Australia's annual consumption. Crucially, the potential for IHP deployment depends on sufficient waste heat availability and may also be curtailed by other site-specific barriers.

Figure 10: Estimated gas use that can be electrified by industrial heat pumps, PJ



Sources: ARENA, Australian government, IEEFA

The F&B sector is the largest opportunity for short-term deployment of IHPs, with the largest gas use to deliver temperatures below 150°C. It may, however, be worthwhile examining some of the "other industry" sectors to verify whether they really require temperatures above 150°C – especially light manufacturing sectors such as textiles, pulp and paper and wood and wood products manufacturing.

Notably, most of the potential for IHP deployment is for temperatures between 150°C and 250°C, particularly for alumina and oil and gas production, where commercially available models are relatively limited. The alumina production process is energy intensive, mostly for preheating and

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[85] IEEFA analysis based on fuel use and process heat demand data in the ARENA report. Food and beverage sectors have been adjusted to account for large amounts of bagasse use, as have pulp and paper sectors to account for use of waste stream for a portion of process heat. Values have been scaled up to the latest available energy use from Australian Energy Statistics.

digesting the bauxite at 140-280°C, while there is a high availability of excess heat at sufficient temperatures to be utilised by a heat pump (for example, exhaust air from the calcination stage).[86]

Mechanical vapour recompression (MVR) is a highly prospective technology that provides a zero emissions pathway for the digestion process by replacing fossil fuel boilers used for steam production.[87] MVR units work as a series of open-cycle heat pumps (as opposed to conventional heat pumps that typically operate in a closed cycle) to recover and reuse heat from the vapor generated in industrial processes, with potentially very high efficiencies and temperature outputs ranging from 80-250°C.[88] For temperatures above 160°C, MVRs are more technologically mature compared with conventional IHPs, and are already used in distillation plants.[89,90]

A study for ARENA identified that MVRs could replace two-thirds of alumina gas use in the next decade,[91] which would add up to about 94PJ per year.[92] They would do so at a very high efficiency, requiring only 1GJ of electricity to replace about 5GJ of gas.[93]

MVR use for alumina refining is in its early stages. In 2021, Alcoa started an MVR pilot project at Wagerup in WA.[94] The project was closed in November 2023 due to significant cost overruns.[95] Despite the challenges, Alcoa believes MVR could play a role in decarbonising the alumina industry. However, it stressed the need for a successful small-scale demonstration before any larger-scale deployment.

In the oil and gas sector, IHPs may present additional financial challenges given the access to cheap gas, and the often remote location of liquefied natural gas (LNG) plants. Given the size of the opportunity, it may however be worth investigating further.

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[86] Energy Conversion and Management. Analysis of technologies and potentials for heat pump-based process heat supply above 150 °C. April 2019. Page 8.

[87] ARENA. A Roadmap for Decarbonising Australian Alumina Refining. November 2022. Pages 24-25.

[88] Alcoa Australia. MVR Retrofit and Commercialisation Report. November 2022. Page 21.

[89] IEA. The Future of Heat Pumps in China. March 2024. Page 65.

[90] ClimateWorks Centre. Pathways to industrial decarbonisation. February 2023. Page 76.

[91] ARENA. A Roadmap for Decarbonising Australian Alumina Refining. November 2022. Pages 3, 15 and 25. Took the midpoint of the percentage of alumina refining energy use contributing to digestion (64%) and the percentage by which MVR could reduce alumina refining emissions (70%).

[92] Based on total gas use for alumina refining of 140PJ in 2023. Australian Aluminium Council. 2023 Sustainability Data.

[93] ARENA. A Roadmap for Decarbonising Australian Alumina Refining. November 2022. Page 18.

[94] ARENA. Full steam ahead for alumina refineries of the future. February 2023.

[95] Alcoa. MVR Evaporation Project Close Out Report. April 2024. Page 20.

IHPs could alleviate expected excess gas demand

Interestingly, the largest gas demand reduction opportunities lie in WA and Victoria, two states facing excess gas demand.[96,97] Victoria is responsible for about half of Australia's gas use in the F&B sector,[98] and WA is responsible for about 78% of Australia's gas use in alumina refining.[99]

IEEFA calculates the application of commercially available heat pumps in the F&B sector could reduce gas demand by nearly 14PJ in the next 10 years in Victoria, which could deliver a 36% reduction in the state's industrial gas use.[100]

In WA, alumina refining consumes about 110PJ of gas a year, or 16% of the state's total gas use.[101] MVR could therefore replace about 74PJ a year, equivalent to 10% of the state's total gas consumption. The gas demand reduction potential could increase to about 89PJ a year if the Worsley Alumina Refinery fully shifts from coal to gas in this period.[102] This would go a long way to avoiding the expected excess gas demand of 69PJ a year in 2031 and 132PJ a year in 2033.[103] This would require an increase in WA's electricity generation equivalent to 10-12% of the state's total electricity use today.[104]

IHPs overlooked in Australia despite their potential

By global standards, the Australian IHP market is in its infancy, and their adoption in Australian industry faces several barriers. One major issue is the low level of awareness and expertise regarding the technical possibilities and economic feasibility of heat pumps among end users, engineering firms, suppliers and other stakeholders. This lack of knowledge extends to the integration of heat pumps into existing industrial processes, which often requires bespoke designs. Heat storage requirements add another layer of complexity, as consistent supply must be ensured. The scarcity of local best practice examples makes it difficult to build confidence in this new type of process heating solution.

Reflecting the limited number of domestic projects, Australia's IHP supply chain is also relatively undeveloped. Most equipment suppliers are based in Europe and Japan, limiting access to essential technologies. Heat pump units in Australia are either fully imported or assembled locally using a

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[96] Australian Energy Market Operator (AEMO). 2024 Gas Statement of Opportunities. March 2024. Page 11.
[97] AEMO. Demand for gas to exceed supply in WA domestic market over next decade. December 2023.
[98] Australian Government. Australian Energy Update 2024. August 2024. Table F.
[99] IEEFA calculation based on total alumina energy use from Australian Aluminium Council's 2023 Sustainability Data; fuel mix and production volumes of alumina plants from ARENA and Deloitte's Roadmap for Decarbonising Australian Alumina Refining; energy use for Worlsey Alumina Refinery from South32's 2024 Sustainability Databook.
[100] IEEFA. Reducing demand: A better way to bridge the gas supply gap. November 2023. Underlying analysis.
[101] See 97 for WA alumina gas use calculations. Total WA gas use comes from: Australian Government. Australian Energy Update 2024. August 2024. Table F.
[102] South32. Sustainable Development Report 2024. Page 64; and South32. Sustainability Databook 2024.
[103] AEMO. 2023 Western Australia Gas Statement of Opportunities. December 2023. Page 5.
[104] Australian Government. Australian Energy Update 2024. August 2024. Table F.

combination of imported and local components, requiring local engineering expertise for system design, project management, and the supply of specific inputs such as piping, wiring and tanks.[105]

In September 2023, a federal government report on emerging trends in Australia's heat pump market provided a detailed view on the residential and commercial landscape, including an overview of supporting government initiatives.[106] It is notable for the absence of information on industrial applications, reflecting the nascent Australian IHP market and lack of policy design and support.

The Australian government's emissions projections also reveal a surprising lack of expected progress in sectors where heat pumps could play an immediate role, such as F&B, with no anticipated emissions reductions from 2025 to 2035.[107] The lack of focus on IHPs is further reflected in recent decarbonisation pathways prepared by Australia's Climate Change Authority, with IHPs mentioned just once and seemingly not modelled in sectors such as F&B, where emissions rise through to 2050.[108,109]

Conclusion

Large-scale IHP pilot project needed in food and beverage sector

The successful outcomes of the Renewable Energy for Process Heat Opportunity Study discussed above underscore the potential of IHPs as a viable alternative to fossil fuels in industrial heat. However, more on-the-ground examples are needed to generate insights, build industry confidence and drive development of service provision and supply chains. Demonstrating the use of IHP technology in existing industrial facilities can help accelerate uptake in the Australian market by:[110]

- Reducing the perceived risk of retrofitting heat pumps for industrial process heating by demonstrating technical and economic feasibility;
- Demonstrating how industrial processes can be managed with onsite renewable energy production, heat pumps, thermal storage and potentially complementary gas-fired boilers;
- Demonstrating how thermal storage can improve the economics of a heat pump solution by reducing capital expenditure, and increasing heat pump utilisation;
- Quantifying the economic and environmental benefits of heat pump systems for industrial process heat applications; and

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[105] Beyond Zero Emissions. Heat pumps supply chain. February 2024. Page 13.
[106] DCCEEW. Heat pumps – Emerging trends in the Australian market. September 2023.
[107] DCCEEW. Australia's emissions projections 2023. November 2023. Page 46. Table 14.
[108] Climate Change Authority. Sector Pathways Review: Industry and waste. September 2024. Pages 4 and 13.
[109] CSIRO. Modelling Sectoral Pathways to Net Zero Emissions. August 2024. Figure 30.
[110] Hardwick Processors. Heat Pump Project: Project Knowledge Sharing Report (Interim). April 2023.

- Providing insights into the electrical supply infrastructure requirements to electrify process heat for industry.

In a 2024 federal budget submission, IEEFA advocated for a dedicated program to implement heat pumps, focusing on the F&B sector. This could help build understanding of technical possibilities and economic feasibility of heat pumps among end users, engineering firms, suppliers and other stakeholders. This could include facilitation of the provision of services and material, and financial support. In terms of scale, it could target replacing 1-2% of food and beverage gas use initially. The program should ensure the actual energy needs of businesses are assessed and that new systems are optimised in terms of size, heat provided, set-up and flexibility, rather than replacing like for like.

Individual sites can gain experience and build confidence by replacing non-critical process heating, including equipment distant from a boiler, which is close to a process that also requires cooling, or which runs at different times or temperatures to most equipment, or to avoid need for a boiler upgrade during expansion.

Further government support would be needed to demonstrate the application of MVRs in the alumina sector, which is a promising solution for decarbonising 70% of an energy-intensive process.[111]

Other measures to support the development of Australia's heat pump supply chain include:[112]

- Setting ambitious deployment targets to provide certainty and encourage supply chain investment;
- Enhancing demand-side incentives through tax concessions or expanding existing initiatives such as the Innovation Hub for Affordable Heating and Cooling program, funded by ARENA;
- Facilitating trading or exchange of waste heat between facilities; and
- Increasing engagement between Australian and leading international heat pump practitioners.

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[111] Alcoa. Renewables and Electrification in Alumina Refining. October 2021. Page 5.
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About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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